

# PULLEYS

## OBJECTIVE:

You will understand the principle of pulleys and will demonstrate their ability to reduce effort when moving a load.

## INTRODUCTION:

A pulley is a grooved wheel mounted on an axle and carrying a string or rope which turns the wheel. Pulleys can be arranged and combined in a variety of ways to make lifting a load easier.

The use of pulleys dates back to ancient times. The works of the Greek poet Homer indicate that pulleys were used on Greek ships to hoist sails as far back as 600 BC. Archimedes (c.287–212 BC) is credited as being the inventor of multiple pulley systems. In response to a challenge from the king of Syracuse, Archimedes reputedly used a pulley system to single-handedly drag a fully loaded three-masted ship onto dry land.

The mechanical advantage (the amount by which a machine makes lifting easier) gained by using a pulley system can be determined by calculating simple ratios: the load divided by the effort needed to move it. The larger the load moved by a given amount of effort, the greater the mechanical advantage. The greater the number of pulleys, the greater the load that can be lifted by a given amount of effort, ignoring friction and the weights of the pulleys themselves.

In this investigation you will explore the principle on which pulleys are based using several different arrangements of pulleys.

## TIME NEEDED:

1 hour

## MATERIALS:

Note: You will need a partner for this investigation.

broom handle	string or cord 3 m long
two chairs with backs of equal height	0.25, 0.5, 1, and 2kg weights
2 double-hooked pulleys of about 8cm diameter	metric spring balance
1 double-hooked pulley of about 5cm diameter	2 metersticks
1 single-hooked pulley of about 5cm diameter	metric ruler
lubricating oil	graph paper
	pencil
	calculator

### *Safety Precautions*

Adult supervision required. Please read and copy the safety precautions at the beginning of this book.

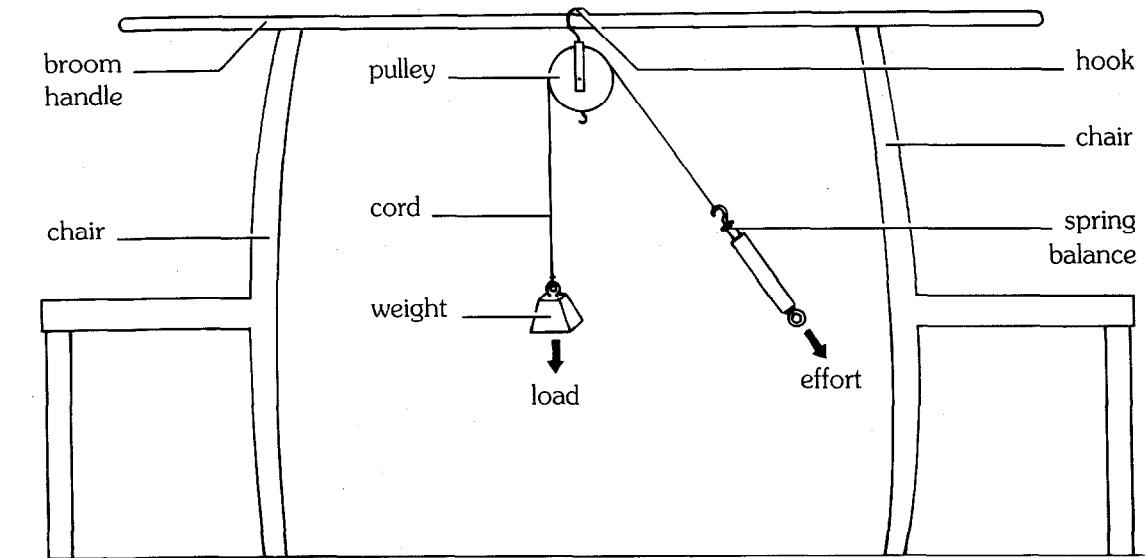
## PROCEDURE:

### ***Part 1—Pulleys and effort***

1. Hang one of the 8cm-diameter pulleys from the broom handle. Support the broom handle on the backs of two chairs about 0.5 m from one another so that the broom handle is horizontal. Tie one end of the string to the 0.5kg weight. Hold the string against the meterstick and measure and mark 80 cm from this end. Pass the string through the pulley and at the 80cm mark, tie the spring balance to the string (see figure 1).
2. Gently pull on the spring balance at a low constant speed and have your partner note the spring balance reading. If the reading is in grams, convert this to kilograms. This is the effort required to lift the load. Forces, including effort, are usually measured in newtons (N). To convert

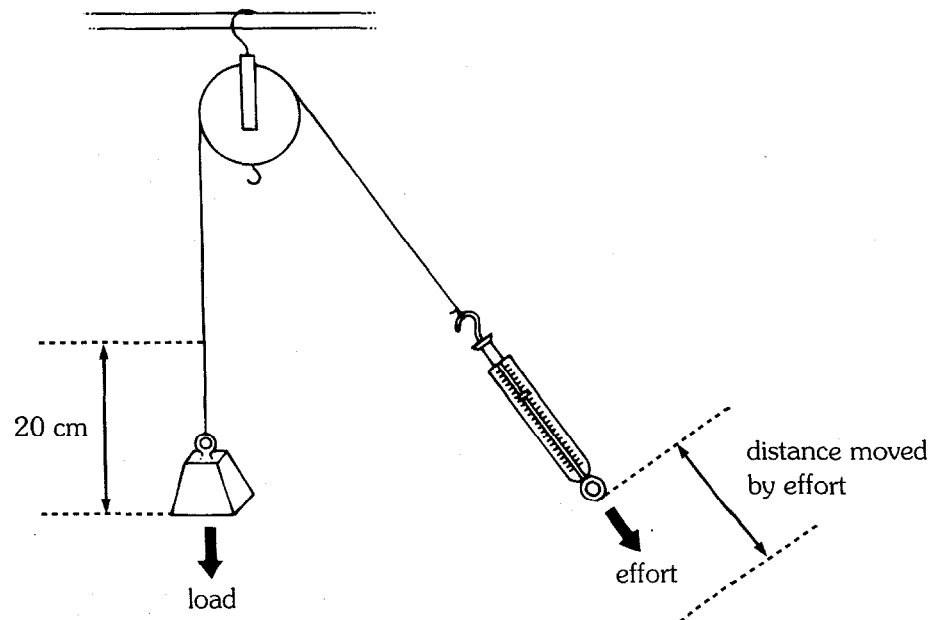
kilograms into newtons, use the following equation: force = mass x acceleration. In this case, acceleration is caused by gravity and has a value of about  $10\text{m/sec}^2$ . So, to convert the effort from kilograms to newtons, multiply the effort (force) by  $10\text{m/sec}^2$ . The load itself is 5 newtons ( $0.5\text{ kg} \times 10\text{m/sec}^2$ ). Enter the value for effort in newtons in the first line of Part 1 of the Data Table in the column marked Effort (N).

Figure 1



3. Find out the velocity ratio (VR) of the pulley by having your partner use the two metersticks to measure the distance traveled by the effort for a 20cm movement of the load (see figure 2). Divide this figure by 20 (the distance traveled by the load), and enter this figure in Part 1 of the Data Table in the column marked Velocity Ratio (VR).

Figure 2



4. Calculate the mechanical advantage (MA—the amount by which the pulley makes lifting easier) by dividing the load (N) by the effort (N). Enter this value in Part 1 of the Data Table in the column marked Mechanical Advantage (MA).

5. Untie the weight and the spring balance from the string.

6. Now set up the arrangement with two pulleys, as shown in figure 3. Tie a loop in one end of the string. Hold the string against the meterstick and measure and mark 120 cm from the loop.

Attach the loop end of the string to the bottom hook of the 8cm-diameter pulley that is hooked over the broom handle. Loop the string around a 5cm-diameter, single-hooked pulley and then around the upper, 8cm-diameter pulley. At the 120cm mark, tie the spring balance to the string, and attach a 0.5kg weight to the lower pulley. Repeat steps 2–4 using this new arrangement. Record your findings in the second line of each column in Part 1 of the Data Table.

7. Untie the spring balance from the string, detach the string from the pulleys, and unhook the string from the top pulley, keeping the loop intact at the end of the string.

8. Set up a three-pulley arrangement (see figure 4). Hold the string against the meterstick and measure and mark 160 cm from the loop in one end. Attach the loop end of the string to the top hook on a two-hooked, 5cm-diameter pulley, and attach the weight to this pulley's lower hook. Loop the string around a single-hooked, 5cm-diameter pulley, then around the two-hooked, 5cm-diameter pulley below it, and then around the two-hooked, 8cm-diameter pulley that is hooked over the broom handle. At the 160cm mark, tie the spring balance to the string. Repeat steps 2–4. Record your findings in the third line of each column in Part 1 of the Data Table.

Figure 3

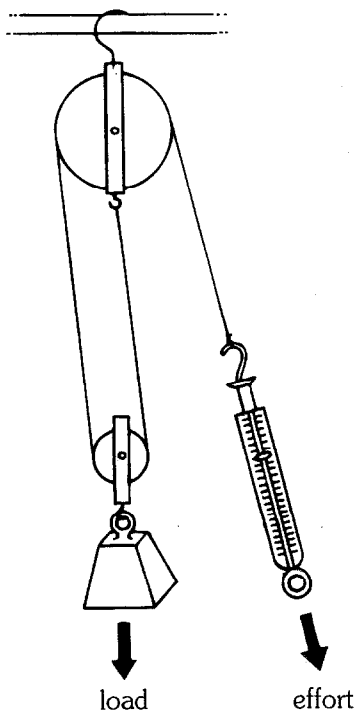


Figure 4

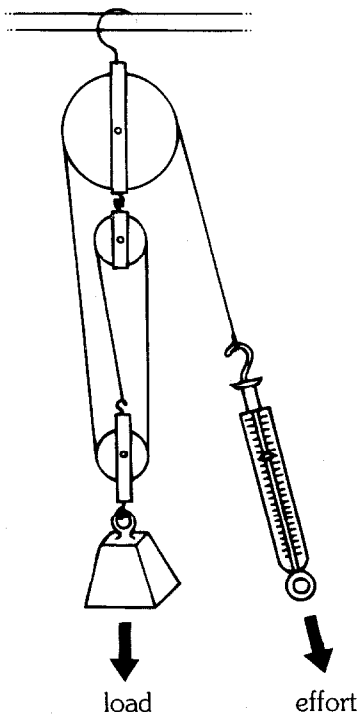
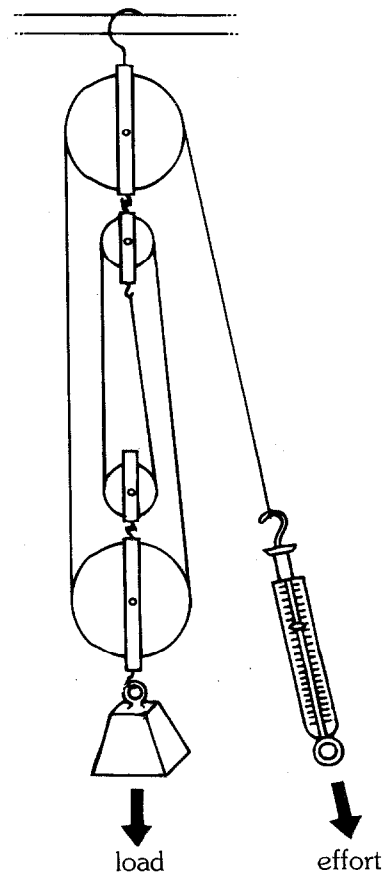


Figure 5



9. Untie the spring balance from the string, detach the string from the pulleys, and unhook the weight from the bottom pulley, keeping the loop intact at the end of the string.

10. Set up a four-pulley arrangement (see figure 5). Before looping the string through the pulleys, hold the string against the meterstick and measure and mark 200 cm from the loop in one end. After setting up the pulleys, tie the spring balance to the string at the mark. Repeat steps 2–4, and record your findings in the fourth line of each column in Part 1 of the Data Table.

**Part 2—Load and efficiency**

11. Using the four-pulley arrangement, repeat step 2, first using no weight (0 kg), then using combinations of the weights to give loads of 0.25 kg (2.5 N), 0.5 kg (5 N), 0.75 kg (7.5 N), 1.0 kg (10 N), 1.5 kg (15 N), and 2.0 kg (20 N). In each case, enter the value for the effort in the column marked Effort (N) in Part 2 of the Data Table.

12. For each load, calculate the mechanical advantage (MA) by dividing the load (N) by the effort (N) and enter the value on the appropriate line in Part 2 of the Data Table, in the column marked Mechanical Advantage (MA).

13. For each load, calculate the efficiency of the system by dividing the mechanical advantage (MA) by the velocity ratio (VR) and multiplying by 100 to give a percentage. The mechanical advantage is different for each load, but the velocity ratio is constant—you calculated this for a four-pulley system in Part 1. Enter the value for efficiency for each load on the appropriate line in the column marked Efficiency in Part 2 of the Data Table.

**DATA TABLE**

Part 1				
No. pulleys	Load (N)	Effort (N)	Velocity ratio (VR) = $\frac{\text{distance moved by effort}}{\text{distance moved by load}}$	Mechanical advantage (MA) = $\frac{\text{load}}{\text{effort}}$
1	5			
2	5			
3	5			
4	5			
Part 2 Four-pulley system				
Load (N)	Effort (N)	Mechanical advantage (MA) = $\frac{\text{load}}{\text{effort}}$	Efficiency = $\frac{\text{MA}}{\text{VR}} \times 100\%$	
0				
2.5				
5				
7.5				
10				
15				
20				

**ANALYSIS:**

1. From your results, what can you conclude about the relationship between the number of pulleys and the velocity ratio (VR)?
2. Does the mechanical advantage (MA)—the amount by which lifting is made easier—increase or decrease with the number of pulleys used?
3. What are the advantages of using a single pulley rather than lifting a load directly, without using a pulley?
4. Plot a graph of Efficiency (as a %) against Load (in newtons) for your results from Part 2. What do these findings tell you about the role played by friction as the load increases?

**OUR FINDINGS:**

Click on above link to see what we found.

## SPECIAL SAFETY NOTE TO INVESTIGATORS

Each invention includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific investigation. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly when you are constructing or demonstrating a model invention. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are carrying out the project, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual projects. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each project you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say **BE CAREFUL WITH HOT LIQUIDS** or **DON'T CUT YOURSELF WITH THE KNIFE** does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

## GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while carrying out these projects. Be sure to check the individual projects in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

### PREPARING:

- Clear all surfaces before beginning projects
- Read the instructions before you start
- Know the hazards of the procedures and anticipate dangers

### PROTECTING YOURSELF:

- Follow the directions step-by-step; do only one project at a time
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
- Make sure there is adequate ventilation
- Do not horseplay
- Wear an apron and goggles
- Do not wear contact lenses, open shoes, loose clothing, or loose hair
- Keep floor and work space neat, clean, and dry
- Clean up spills immediately
- Never eat, drink, or smoke in laboratory or work space
- Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

## USING EQUIPMENT WITH CARE:

- Set up apparatus far from the edge of the desk or bench
- Use knives and other sharp or pointed instruments with caution
- Pull plugs, not cords, when removing electrical plugs
- Clean glassware before and after use
- Check glassware for scratches, cracks, and sharp edges
- Clean up broken glassware immediately
- Do not touch metal conductors
- Use only low voltage and current materials such as lantern batteries
- Be careful when using stepstools, chairs, and ladders
- Never look directly at the sun with your observation devices

## USING CHEMICALS:

- Never taste or inhale chemicals
- Label all bottles and apparatus containing chemicals
- Read labels carefully
- Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
- Do not touch chemical solutions
- Wash hands before and after using solutions
- Wipe up spills thoroughly

## HEATING SUBSTANCES:

- Use goggles, apron, and gloves when boiling water
- Keep your face away from test tubes and beakers
- Never leave apparatus unattended
- Use safety tongs and heat-resistant mittens
- Turn off hot plates, bunsen burners, and gas when you are done
- Keep flammable substances away from heat
- Have fire extinguisher on hand

## FINISHING UP:

- Thoroughly clean your work area and glassware
- Be careful not to return chemicals or contaminated reagents to the wrong containers
- Don't dispose of materials in the sink unless instructed to do so
- Wash your hands
- Clean up all residue and put in proper containers for disposal
- Dispose of all chemicals according to all local, state, and federal laws

## BE SAFETY CONSCIOUS AT ALL TIMES